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EFFECT OF pH ON CAKE VOLUME AND CRUMB BROWNING[1]

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ABSTRACT

Excessive browning of cake crumb may occur when high concentrations of honey or other sweetening agents containing reducing sugars are used. Excessive browning is accelerated by increase in pH, typical of the Maillard reactions. The undesirable effect can largely be eliminated by use of a leavening acid to maintain the pH of the crumb at approximately 6.3. The addition of a leavening acid, however, accelerated the loss of carbon dioxide during mixing of the cake batter. This resulted in partial loss of cake volume.

Loss of carbon dioxide during mixing was materially reduced and the pH of the cake crumb controlled by coating the leavening acid with hydrogenated vegetable oil. The acid released by heat during the latter stages of baking controlled the final pH and browning of the cake crumb.

Honey and dextrose are used widely in various types of baked goods. The amount and types of honey which can be used in bread, cake, sweet doughs, and cookies has been dealt with in previous publications from this laboratory (5, 6, 7, 8). Special problems arise, however, when honey is used in cake. First, it causes loss in volume which can be overcome by increasing the amount of soda leavener (6). However, increasing the amount of soda may cause excessive browning in the interior, especially in white cakes. This objection applies when any reducing sugars (honey, corn sugar, invert sugar) in moderate concentration are used. The role of the Maillard reaction in baked products has been discussed (2, 3, 4) and will not be dealt with here.

It is well known that the Maillard reaction is accelerated with an increase in pH. Thus in cake crumb, the amount of browning depends upon the final crumb pH. Most of the cake-crumb browning occurs near the end of the baking period, and considerable improvement in color results at the higher pH levels if the baking time is kept to a minimum. Cakes invariably brown more near the bottom of the pan and thus it is difficult to obtain a representative sample for reflectance studies, measurement of optical density, reducing value, or other changes generally associated with browning. In this study, the primary interest was in baking at a pH which was low enough to inhibit browning of the cake crumb in batters which contained high levels of reducing sugar. It has been observed repeatedly that with a crumb pH

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of approximately 6.3 the visible effects of browning are insignificant. The volumes of the cakes, however, generally were lower with a drop in pH from neutral, so that baking in this pH region to inhibit browning was unsatisfactory. A study was therefore made to determine the cause of the poor volume and how it could be overcome while at the same time controlling the crumb color.

Materials and Methods

A white pound-cake formula was used in all experiments reported here. The composition was as follows:

	g.
Flour	200
Sucrose	100
Honey	125
Shortening	100
Egg white	120
Milk powder	20
Salt	6

All cakes were baked at 350°F. for 30 minutes. The amount and type of leavening agent were as described in the individual experiment.

In industry the activity of a baking powder is measured in a special apparatus (1). A standard batter is mixed in a closed container and the increase in volume of the batter and atmosphere is measured on a gasometer. In this work, it was desired to have a direct measure of the carbon dioxide that escapes from the batter. Also it was desired to have the same type of mixing as used in the baking laboratory and to be able to use the batter for subsequent baking. A rubber hood, there-

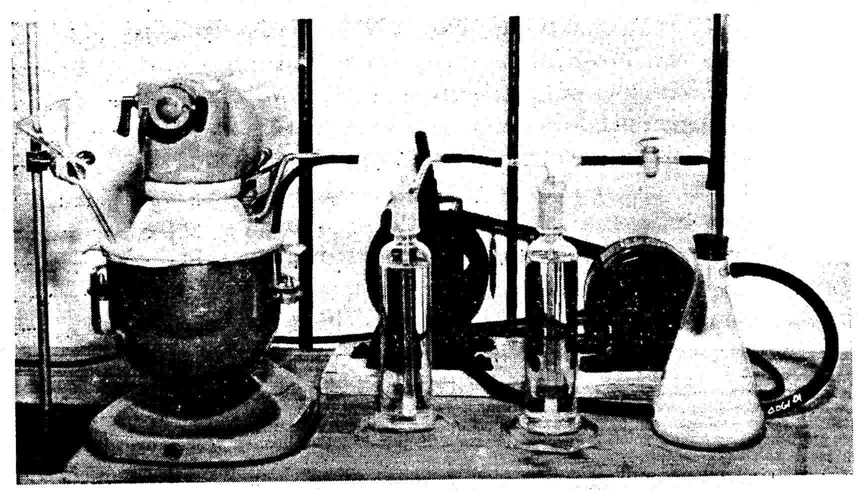

Fig. 1. Apparatus for measuring carbon dioxide escaping from the batter during mixing. The train includes two gas absorption bottles and a moisture trap containing calcium chloride.

fore, was fashioned for the Hobart mixer, Model N-50, so that the gases evolved during mixing could be collected and measured. Inlet and outlet connections were made on the rubber hood to permit air to be drawn over the batter as it was mixed. During operation, air was drawn continously and at a constant rate through the bowl. The outlet gases were passed through two gas-absorption bottles containing barium hydroxide solution (Fig. 1). The excess barium hydroxide was titrated with standard hydrochloric acid to a phenolphthalein end point as a measure of the carbon dioxide escaping from the batter.

A sequence of mixing was adopted as follows:

	Time involved (minutes)
1. Mix honey, sucrose, shortening, salt, milk powder	1
2. Add half the egg whites and continue mixing	5
3. Add flour (sifted with soda and leavening acid) and remainder of egg whites; attach hood, start mixer, and begin drawing air through mixing bowl	1
4. Add water slowly while mixing	2
5. Continue mixing	1
6. Stop mixer, but continue drawing air through bowl	11
7. Remove hood and weigh 6 oz. of batter into pans for baking	5

A coated potassium bitartrate was prepared by blending equal parts by weight of potassium bitartrate and hydrogenated vegetable oil (m.p. 150°F.). The material was heated until the fat melted and then was allowed to solidify while being stirred briskly. The solidified material was ground to particles fine enough to pass a 65-mesh screen. It was found that the addition of a small amount of n-butanol to the melted mixture produced a material that crumbled more readily after setting. The coating was more effective if the particles of leavener were coarse. The particle size reported above is an upper limit beyond which a mottled color effect was produced in the cake crumb, indicating local excesses of acid.

Results and Discussion

A series of batters was prepared with various levels of potassium bitartrate and each batter containing 2.5 g. of soda, incorporated by sifting with the flour. The carbon dioxide loss in mixing was determined for these batters by the procedure outlined. Six-ounce quantities of batter were subsequently weighed into pans and baked 30 minutes at 360°F. The volume and crumb pH[3] of these cakes were measured. These data are presented in Table I and Fig. 2.

Carbon dioxide losses were corrected for the volume of carbon dioxide in the air drawn over the batter, which was found to be 3.0 ml.

[3] Ten grams of cake crumb were dispersed in 50 ml. of water and the pH measured directly on the slurry.

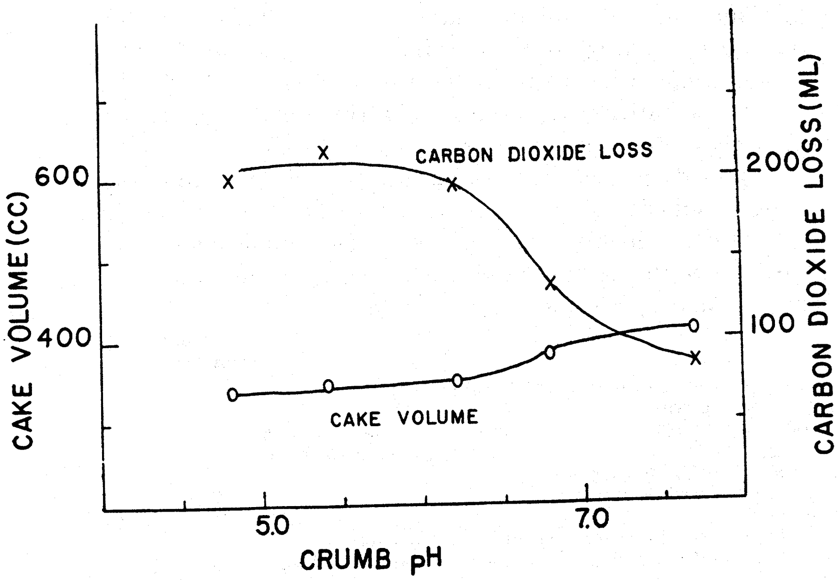

Fig. 2. The effect of crumb pH on carbon dioxide loss and cake volume.

TABLE I

EFFECT OF POTASSIUM BITARTRATE ON CAKE VOLUME, CARBON DIOXIDE LOSS, AND CRUMB PH

SAMPLE	POTASSIUM BITARTRATE	LOAF VOLUME	CARBON DIOXIDE LOSS	CRUMB pH
	g.	*ml.*	*ml.*[b]	
1 (Control)[a]	. . .	500	158	6.8
2	3	507	87	7.7
3	5	485	129	6.8
4	7	447	195	6.2
5	9	447	210	5.4
6	12	440	197	4.8

[a] Contained 10 g. of commercial baking powder with no additional soda.
[b] At 0°C. and 760 mm. pressure.

It can be seen that carbon dioxide loss increased in a pronounced manner with drop in crumb pH. The results reported above are, of course, highly empirical. It is necessary to standardize each step of the mixing process to obtain reproducible results. Although these data were determined for soda and potassium bitartrate, a similar but not so pronounced effect was observed when conventional baking powder was employed and the crumb pH was lowered with potassium bitartrate.

It has been pointed out that the crumb pH should be approximately 6.3 to effectively inhibit browning, but that this caused excessive premature loss of the carbon dioxide in the batter during mixing. Browning becomes marked, however, only in the latter stages of baking. An experiment was therefore devised in which regular baking powder was used in combination with coated potassium bitartrate. The coating was selected to melt only on heating and in time to liberate the acid to prevent browning. The most effective method devised to coat the acid was that already described. Its influence on volume was demonstrated in the following experiment:

White pound-cake batters were prepared containing the normal amount of baking powder plus an additional leavening acid. The formula used was that described under "Materials and Methods" except that the size of the batter was increased threefold. A batter without the honey and additional acid was used as control. The procedure in each case was to prepare the batter and then put 6-oz. samples into pans at various time intervals after mixing. The crumb pH was determined for the first and the last cake of each of the time series. These data are reported in Table II and Fig. 3.

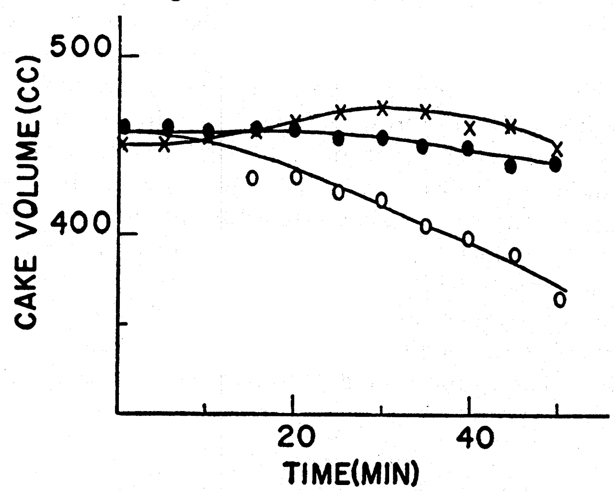

Fig. 3. Stability of cake batters. X, Sucrose standard with no honey; open circles, honey cake with coated potassium bitartrate; solid circles, honey cake with uncoated potassium bitartrate.

These data show that the sucrose batter at the pH level of 6.88 (Sample 1) did not deteriorate on standing, since the volumes of the cakes were essentially the same over a 50-minute resting period. Batter No. 2, pH 5.9, which contained the coated bitartrate, yielded similar results. In the cake batter that contained untreated bitartrate, the cake volumes became progressively lower with standing time (Sample 3). Undoubtedly, the size of the batter influences the rate of loss of carbon dioxide. The insignificant loss of volume at zero time shown by these data is believed to be due to the rather large batters employed.

TABLE II

Stability of Cake Batters

Time	Sample 1[a]		Sample 2[b]		Sample 3[c]	
	Cake Volume	Crumb pH	Cake Volume	Crumb pH	Cake Volume	Crumb pH
minutes	*ml.*		*ml.*		*ml.*	
0	450	6.88	460	5.90	460	5.85
5	450	...	460	...	460	...
10	455	...	455	...	460	...
15	455	...	460	...	430	...
20	465	...	460	...	430	...
25	470	...	455	...	430	...
30	470	...	455	...	420	...
35	470	...	450	...	405	...
40	460	...	450	...	400	...
50	450	6.88	445	6.00	365	...

[a] Standard containing sucrose and commercial baking powder.
[b] Honey cake with coated potassium bitartrate.
[c] Honey cake with uncoated potassium bitartrate.

Manufacturers of baking powder recognize that carbon dioxide loss during mixing must be minimized, even in neutral batters. This has been accomplished by the use of the moderately insoluble monocalcium phosphate, or a coated monocalcium phosphate (9). For cakes having an acid crumb, required to inhibit browning, the controlling of the loss of carbon dioxide is even more important. Although loss of carbon dioxide may be minimized in batters having an acid reaction by baking shortly after mixing, this is not always possible in commercial cake production. In cake production using honey, the control of the pH of crumb in the acid range is important, particularly in the later stages of baking when the temperature is high enough to accelerate the crumb browning. The use of the coated leavening acid provides the necessary acid, only late in the baking process, when it is required for the control of crumb browning.

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Literature Cited

1. Barackman, R. A. Chemical leavening agents and their characteristic action in doughs. Cereal Chem. 8: 423–433 (1931).
2. Griffith, T., and Johnson, J. A. Relation of the browning reaction to storage stability of sugar cookies. Cereal Chem. 34: 159–169 (1957).
3. Griffith, T., Johnson, J. A., and Northam, J. I. Factors affecting color stability of stored sugar cookies. Cereal Chem. 34: 153–159 (1957).
4. Haney, H. N. Browning reactions in baked products. Master's Thesis, Kansas State College (1952).
5. Smith, L. B., and Johnson, J. A. The use of honey in bread products. Bakers' Digest 25(6): 103–106 (1951).

6. SMITH, L. B., and JOHNSON, J. A. The use of honey in cake and sweet doughs. Bakers' Digest **26**(6): 113–118 (1952).
7. SMITH, L. B., and JOHNSON, J. A. Honey, its value and use in popular cookies. Bakers' Digest **27**(2): 28–31 (1953).
8. SMITH, L. B., and JOHNSON, J. A. The use of honey in white and whole wheat bread. American Bee J. **94**(3): 118–119; **94**(4): 164–165 (1953).
9. VAN WAZER, J. R., and ARVAN, P. G. Chemistry of leavening. Milling Production **19** (2): 5–8, 22; (3): 5-7, 9 (1954).